Title: Conductivity of Salt Solutions

Brief Overview:

Data is collected using the CBL with a conductivity probe in an experiment by varying the concentration of three different salts in aqueous solutions. This data will then be graphed and analyzed using the TI-82.

Links to Standards:

- **Mathematics as Problem Solving**
  The students will investigate the effect of varying concentrations of three different ionic compounds on conductivity of aqueous solutions and make predictions based on their observations.

- **Mathematics as Communication**
  The students will work cooperatively to express their findings in writing and to develop a generalization of their investigation.

- **Mathematics as Reasoning**
  The students will draw conclusions based on the collected data.

- **Mathematical Connections**
  The students will connect an algebraic equation to the graphical representation of salinity in Earth Science, Biology, or Chemistry applications.

- **Algebra**
  The students will write an algebraic equation that describes the variation of conductivity with concentration.

- **Statistics**
  The students will use graphing calculators to determine the equation for the line of best fit.

Grade/Level:

Algebra II

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- Graphing and identifying linear functions
- Entering data in the statistical lists on the TI-82
- Graphing a scatter plot
- Performing a regression to fit the data
- Graphing a regression curve by importing into the "Y=" list of the TI-82
- Accessing a program stored in the TI-82
- Linking the CBL, TI-82 and conductivity probe

Objectives:

Students will:

- work cooperatively in teams.
- describe the relationship between conductivity and concentration**.**
- describe the relationship between conductivity and the number of ions.
- predict the slope of a linear equation with *n* number of ions.

Materials/Resources/Printed Materials:

- CBL system
- TI-82 calculator
- Vernier conductivity probe
- "CHEM" TI-82 program from Vernier
- 1 Molar solution of Sodium Chloride (1.0 M NaCl) in a dropper bottle
- 1 Molar solution of Calcium Chloride (1.0 M $CaCl_2$) in a dropper bottle
- 1 Molar solution of Aluminum Chloride (1.0 M $AlCl_3$) in a dropper bottle
- 100 ml beakers
- Stirring rod
- Goggles
- Holmquist, Dan, Jack Randall, and Donald L. Voltz. *Chemistry with the CBL*. Portland, OR: Vernier Software. 1995.

Development/Procedures:

1. The teacher will prepare the solutions as described below:

   a. 1.0 M NaCl: weigh 5.85 g of NaCl and dissolve in 100 ml distilled water. Pour into the labeled dropping bottles.

   b. 1.0 M $CaCl_2$: weigh 11.0 g of $CaCl_2$ and dissolve in 100 ml distilled water. Pour into the labeled dropping bottles.

c. 1.0 M $AlCl_3$: weigh 24.0 g of $AlCl_3$ and dissolve in 100 ml distilled water. Pour into the labeled dropping bottles.

2. The teacher or student will:

   a. Load the "CHEM" or "CHEMBIO" program into your TI-82. Note: any program that will allow you to monitor the output of the conductivity probe is useable.

   b. Connect the conductivity probe, CBL and TI-82 as shown in the student lab worksheet.

   c. Clear the TI-82 calculator in the Y= menu.

   d. Turn both the CBL unit and the calculator on and follow the directions given in the student worksheet.

Performance Assessment:

- The student worksheets will be collected and graded.
- A class discussion will follow the lab in order to assess student comprehension.
- When appropriate, students may be asked to reconfigure the experiment using new ionic compounds of their choice.

Extension:

- Repeat the experiment using KCl and compare the results to that of NaCl.
- Repeat the experiment using $MgCl_2$ and compare to the results to that of $CaCl_2$.
- Repeat the experiment using $Al_2(SO_4)_3$ and predict the slope of the line.

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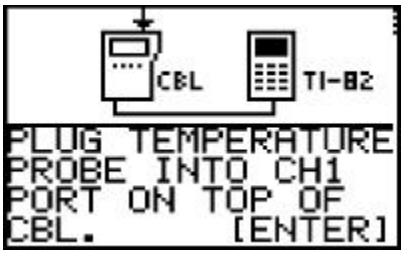
STUDENT WORKSHEET STUDENT'S NAME_____

PART A

1. **Safety first!** Wear safety goggles.
   Students will work in groups of two and alternate roles of experimenter and recorder.

2. Connect the conductivity probe, CBL and TI-82 as shown below.



3. Add 100 ml of distilled water in a beaker/styrofoam cup. Place the conductivity probe in water.

4. Start the "CHEM" or other program on the TI-82. Choose 0-2,000 μS as your range when asked. Make sure that the switch on the amplifier box connected to the probe is adjusted to 0-2,000 also.

5. Use the stored or other calibration in the "CHEM" program.

6. Follow the set-up outline in the program until the first conductivity value appears on the CBL. Record this value as the initial value in your data table.

7. Using the 1.0M NaCl solution add one drop to the water in the cup/beaker. Stir. Record the conductivity reading. Continue to add one drop at a time, stirring and recording the conductivity value after each addition.

8. Rinse the conductivity probe with distilled water.

9. Repeat steps 3-8 with 1.0M $CaCl_2$.

10. Repeat steps 3-8 with 1.0M $AlCl_3$.

STUDENT'S DATA TABLE

# of drops 1.0M NaCl	conductivity (μS)	# of drops 1.0M $CaCl_2$	conductivity (μS)	# of drops 1.0M $AlCl_3$	conductivity (μS)

PART B

1. Using graph paper, graph each set of data on the same set of coordinates. Label each axis, include units, name the graph and include key.

2. Using the TI-82 graphing calculator, enter:
   a. List 1: 0-10
   b. List 2: conductivity of NaCl
   c. List 3: conductivity of $CaCl_2$
   d. List 4: conductivity of $AlCl_3$
   e. Use STAT PLOTS to plot the data set (L1, L2).
   f. Perform a linear regression on (L1, L2).
   g. Repeat steps e and f for (L1, L3).
   h. Repeat steps e and f for (L1, L4).
   i. Print the graph using "TI-Graph Link" program

PART C - DISCUSSION QUESTIONS

1. Write the equation of each line.

   NaCl_____

   $CaCl_2$_____

   $AlCl_3$_____

2. Identify the slope of each line.

   NaCl_____$CaCl_2$_____$AlCl_3$_____

3. Calculate the whole number ratio of the slopes.

   NaCl_____$CaCl_2$_____$AlCl_3$_____

4. What is the number of ions in each compound?

5. What is the relation of the number of ions to the slope of each line?

6. a. What conductivity value would you expect using 15 drops of each solution?

   NaCl_____$CaCl_2$_____$AlCl_3$_____

   b. Using 25 drops?

   NaCl_____$CaCl_2$_____$AlCl_3$_____

7. What is conductivity?

8. What conductivity value would you expect if 7 drops of 1.0M Potassium chloride (KCl) were added to 100 ml of distilled water? Why?

9. What is the ***r*** value for each of the linear equations?

   NaCl_____$CaCl_2$_____$AlCl_3$_____

10. What value of ***r*** would indicate a perfect fit?

11. Predict the slope of the line for a 1.0M solution of Aluminum sulfate, $Al_2(SO_4)_3$.

TEACHER RESOURCE

Ionic compounds in aqueous solutions at low concentrations dissociate completely.

$NaCl_{(aq)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$	**2** ions are formed.
$CaCl_{2(aq)} \rightarrow Ca^{+2}_{(aq)} + 2Cl^{-}_{(aq)}$	**3** ions are formed.
$AlCl_{3(aq)} \rightarrow Al^{+3}_{(aq)} + 3Cl^{-}_{(aq)}$	**4** ions are formed.

The slopes of the linear equations will be in the ratio of **2:3:4**.

Data for each linear function should fit the linear regression with $\boldsymbol{r} \geq 0.97$.

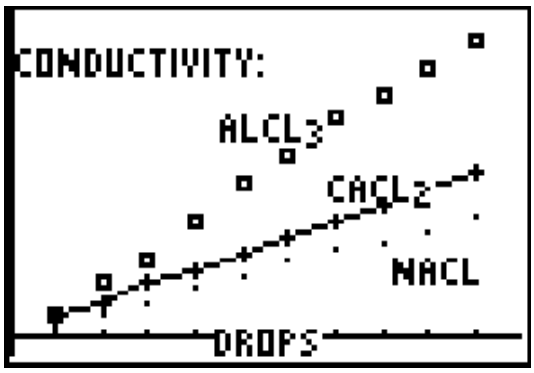
$Al_2(SO_4)_{3\ (aq)} \rightarrow 2Al^{+3}_{(aq)} + 3SO_4{}^{-2}_{(aq)}$	**5** ions are formed.

The Vernier Conductivity Probe measures the ability of a solution to conduct an electric current between two electrodes. In solution, the current flows by ion transport. Therefore, an increasing concentration of ions in the solution will result in higher conductivity values (Vernier 1996). The probe is actually measuring *resistance*, defined as the reciprocal of conductance. When resistance is measured in ohms, conductance is measured using the SI unit, *siemens* (S). Since the siemens is a very large unit, aqueous samples are commonly measured in microsiemens, μS.

Sample results:

L1	L2	L3	L4
1.0000	47.400	80.600	90.300
2.000	80.600	128.00	194.00
3.000	128.00	194.00	275.00
4.000	180.00	237.00	390.00
5.000	213.00	294.00	530.00
6.000	261.00	350.00	630.00
7.000	303.000	460.00	745.00

L1(1)=1 L2(7)=303



LinReg
y=ax+b
a=40.656
b=8.693
r=.998

SODIUM CHLORIDE